Molarity Discovery Through Titration Lab Report

Michael B. Bradley

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Acknowledgments

Rahul	Educational Peer and Friend
David Kim	Chemistry Teacher
Erik	Educational Peer and Friend

Introduction

Although many phenomena are first observed in the field and in one's natural environment, lab's like this one act as a standardized method of observing scientific interactions. A controlled environment enables researchers to focus on the individual dependent variables of an interaction, instead of needing to sift through the results of large groups of changing variables without having the ability to remove previously determined and/or measured independent variables.

Titration

Titration is the chemical method used to discover the concentration of an unknown acidic/basic solution by measuring the total amount of acidic/basic solution that is required to neutralize the unknown solution. When the contributing solution has a known concentration, it is possible to determine the other solutions concentration by using an equality of the compound ratios of each solution:

$$\frac{M_1 \cdot V_1}{n_1} = \frac{M_2 \cdot V_2}{n_2}$$

The M, V, and N(s) stand for molarity, volume, and mole ratio of each solution respectively. This equation can be solved for each variable independently when all other variables are known, a simple concept of algebra.

Solution

Solutions are mixtures that contain their components integrate within one another evenly. This gives off the physical property that it is difficult if not impossible to separate the components of a solution after they have been mixed together. Solutions still follow the same laws that are common in algebra which enables one to use their attributes in combination with other formulas and concepts. For example, if a solution contains two components, the following equality is true:

$$m(A \,\&\, B) = m_A + m_B$$

In word format: the solution of the two components together is equivalent to the mass of each component separately summed together.

As well as this property, Earth's favorite liquid water is capable of dissolving many substances, and this includes substances that are composed of ions of extra Hydrogen ions and Hydroxide ions.

Molarity

Molarity is a unit of measurement used for communicating the concentration of a specific sub-

stance within a solution. It follows the format $\frac{\text{mol}_A}{L_B}$, where A is the first substance and B is the solution containing substance A. But the usage of molarity is not limited to measurement records. It can also be taken advantage of to determine the amount of moles of a substance that exist in a solution through the use of stoichiometry:

$$\frac{\text{mol}_A}{L_B} * \text{measurement}\, L = \text{total mol}$$

Acids

Acids are water based solutions that contain excess hydrogen ions. When combined with a base the excess hydrogen is combined with the excess hydroxide of the base, resulting in a more neutral solution. That is, until the excess hydrogen runs out, and excess hydroxide begins to accumlate.

Bases

Bases are water based solutions that contain excess hydroxide ions. When combined with an acid the excess hydroxide is combined with the excess hydrogen of the acid. The same properties of acids discussed above, apply reciprocally to bases.

Neutralization

Neutralization, as partially discussed above, is the process by which excess Hydrogen ions are combined with excess Hydroxide ions. This reduces the concentration of the excess ions. In this lab, one combines two solutions of opposing pH(s) which results in solution neutralization. The equality that was described above demonstrates how the variables that control whether a solution is neutralized by its opposing solution are determined on strict and predictable values.

Indicators

Indicators are substances that rely on accepting or dispersing Hydrogen or Hydroxide ions. When they lose Hydrogen or Hydroxide they will change in some way that indicates to an observer their current state. This is commonly a physical change that includes a change of hue or saturation. Litmus paper is a common indicator that changes hue when placed in different pH solutions.

Phenolphthalein

Phenolphthalein is the indicator that will be used in this lab and changes its hue in varying pH.

Prerequisites

- Stoichiometry

Purpose

The purpose of this lab is to determine the molarity of an unknown solution, or an analyte, through the process of titration. This includes using pH indicators such as phenolphthalein in order to accurately track the change in pH of the solution as titrant is contributed to help locate the equivalence point, and by consequence the volume of titrant necessary to neutralize the solution.

Materials

- 0.5 M NaOH Solution
    - Base solution to donate [OH^-] ions as the titrant.
- X M HCl Solution
    - Acidic solution to donate [H^+] ions as the analyte.
- 2 - 100mL Beakers
    - Hold the NaOH and HCl solution until it can be deposited into the Erlenmeyer flask.
- 10mL Phenolphthalein
    - Visually detect the pH level of the new solution.
- Graduated Cylinder
    - Measure out the Hydrochloric acid before adding it to the flask.
- Safety Goggles
    - Protect your seeing balls from the harmful effects of Hydrochloric acid.
- ≥ 30mL Volumetric Burette
    - Dispense a controlled flow of titrant solution while also precisely measuring the volume of titrant used to neutralize the analyte.
- Burette Stand and Clamp
    - Securely hold the burette while titrant is being dispensed so as not to cause unnecessary spillage when neutralizing the unknown solution.
- Pipette
    - Used to deposit Phenolphthalein in the analyte and titrant into the burette.
- 125mL Erlenmeyer Flask
    - Hold new solution of analyte and titrant and help facilitate mixing of the two substances.
- Standard Lab Acquisition Materials
    - Procedure guide, data table, and writing utensil

Procedure

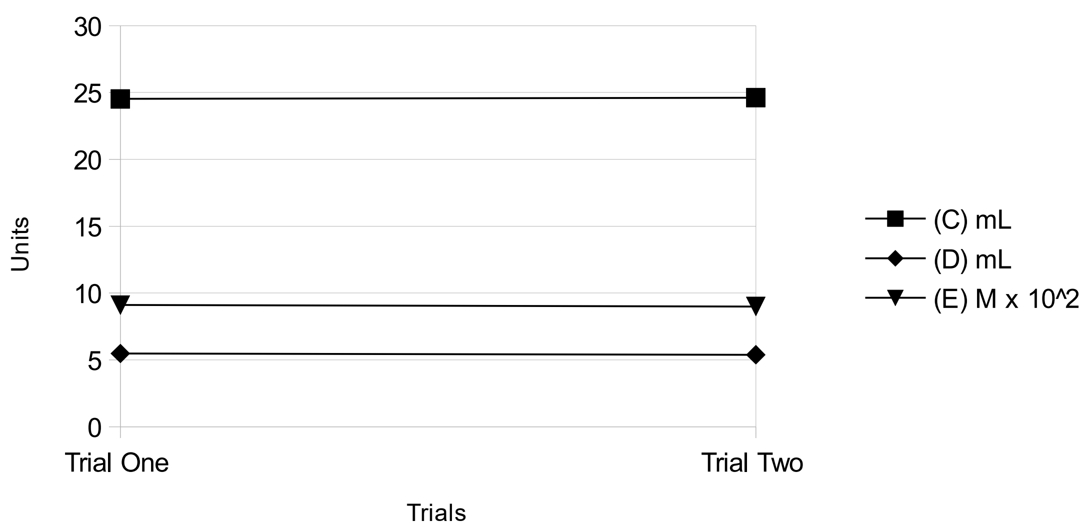
1. Collect the Standard Lab Acquisition Materials.
   1. Put on goggles.
2. Retrieve three beakers:
   1. At least 10mL of HCl
   2. At least 30mL of NaOH
   3. At least 5mL of phenolphthalein
3. Pour 10mL of the Hydrochloric acid into the graduated cylinder.
   1. Empty the 10mL of fluid in the cylinder into the Erlenmeyer flask.
4. Pour 20mL of distilled water into the cylinder.
   1. Empty the 20mL of fluid in the cylinder into the flask.
5. Use the pipette to transfer 4 drops of phenolphthalein into the flask.
6. Setup the burette on its stand on the desk if it isn't setup already.
   1. Optionally rinse the burette if it is not already clean.
7. Pour 30mL of Sodium hydroxide into the burette.
8. Place the Erlenmeyer flask beneath the burette.
9. Use the control on the side of the burette to release drops of the titrant (Sodium hydroxide).
   1. Pause between drops to swirl the flask with a circular motion of the wrist until the color of the solution returns to clear.
10. Repeat steps 8 and 9 until the color is replaced with a faint glow of magenta that takes a longer period of time to dissipate.
    1. Measure volume value on the burette.
11. Empty the flask into the drain.
12. Even though the solution should be neutralized, keep the water running in order to better protect the school pipes.
13. Repeat procedure for second trial.
14. Follow standard cleaning procedure after each lab.
    1. Collect and return equipment.
    2. Return excess chemicals.
    3. Return goggles.

Lab Results

Table 1: Variables of Titration Trials

	Trial One	Trial Two	
(A)	30.0mL	30.0mL	Volume of analyte
(B)	30.00mL	30.00mL	Burette reading before neutralization of analyte
(C)	24.52mL	24.62mL	Burette reading after neutralization of analyte
(D)	5.48mL	5.38mL	Volume of titrant used to neutralize analyte
(E)	0.091 M	0.090 M	Molarity of analyte

Graph 1: Change Between Trials



Qualitative Data

The only measurable visible changes that had occurred during this lab were apparent while titration was being performed. Every time a drop of Sodium hydroxide was deposited into the Erlenmeyer flask that held the analyte, the phenolphthalein would change colors vibrantly and make the solution magenta for a few seconds at a time until the solution became clear once more. This pattern persisted until the titration is close to reaching the equivalence point, at which time the magenta phase of the cycle resides longer until it becomes a permanent state, indicating one has reached the endpoint of the solution and the titration lab.

Analysis

Based on the graph produced in the lab results section of this report, one can assume that the lab yields fairly consistent data across multiple trials. The subtle differences that appear between the trials would seem to indicate that the experiment is heavily dependent upon small changes in records. Although in terms of dependency, the equivalent starting records of the volume of the analyte and the initial burette reading show consistency in the testing procedure.

Calculation of Results

This lab requires the use of a surprisingly small amount of mathematical knowledge. The first step that requires the use of algebra only concerns addition and its relative subtraction. By taking the measurement of the burette before any titrant was released and subtracting from it the measurement of the same burette after the analyte was neutralized, one can acquire the total amount of titrant used during the titration.

$$30.00\text{mL} - 24.52\text{mL} = 5.48\text{mL} \qquad (B_1, C_1) \rightarrow (D_1)$$

$$30.00\text{mL} - 24.62\text{mL} = 5.38\text{mL} \qquad (B_2, C_2) \rightarrow (D_2)$$

With the volume of fixed molarity titrant known, it is now possible to calculate the molarity of the analyte used in the lab. This can be done by equating the mole ratios of the analyte and the titrant. Note that the value 0.5M is a known constant of the concentration of the titrant.

$$\frac{E_1 \cdot 30.0\text{mL}}{1\text{mol}} = \frac{0.5\text{M} \cdot 5.48\text{mL}}{1\text{mol}} \qquad \frac{0.5\text{M} \cdot 5.48\text{mL}}{30.0\text{mL}} = 0.091\text{M} \qquad (A_1, D_1) \rightarrow (E_1)$$

$$\frac{E_2 \cdot 30.0\text{mL}}{1\text{mol}} = \frac{0.5\text{M} \cdot 5.38\text{mL}}{1\text{mol}} \qquad \frac{0.5\text{M} \cdot 5.38\text{mL}}{30.0\text{mL}} = 0.090\text{M} \qquad (A_2, D_2) \rightarrow (E_2)$$

$$\frac{0.091\text{M} + 0.090\text{M}}{2} = 0.091\text{M} \qquad \text{Final result average:} \qquad (E_1, E_2) \rightarrow (E)$$

Evaluation

The low calculated molarity along with the equal mole ratios explains why one has to add a much smaller amount of titrant into the large sample of analyte in order to neutralize the solution. At the low molarity (0.091M), the analyte has very few Hydrogen ions to contribute to the total solution. Although the analyte occupies a larger volume, the higher concentration of the titrant (0.5M) enabled a greater number of Hydroxide ions to be released to combine with the Hydrogen ions of the analyte, resulting in excess water molecules and a neutralized solution.

Conclusion

By completing this lab one was able to accurately determine the concentration of an solution through the process of titration. The process has also demonstrated itself to be very predictive in terms of receiving accurate results that limit the range of mal-measurement.

This lab was able to conclude that the substance that was being used as the titrant in this specific case was approximately 0.091M. This is not equivalent to the literal value for the concentration of the titrant but it is close enough to assume that the method of titration is adequate for measuring the concentration of substances that require moderately precise results. The results of this lab have proposed and determined that for solutions to be neutralized a proportionate amount of each must be mixed together based on their pH concentration. And from the values that are recorded when the proportions are measured, the molarity of a solution in terms of its acidic contents can be calculated.

Although the lab was precise, the results are less than perfectly accurate, and this could have been caused by an assortment of issues. The first of which is a precision error that can occur within the burette. Most burettes have measurements on their sides that allow for the user to record the amount of liquid within the burette, but inaccuracies within the plastic moldings or glass can prevent the measurement labels from being precise. Error can also arise from the flow rate that is permitted by the burette. The burette uses a valve in order to release and disclose liquid into another medium. The valve has a certain amount of tension consistently applied to it, and this friction prevents a precise method of controlling the flow rate when dispensing the titrant into the analyte.

This lab demonstrated the use and mathematical principles of ratios and how it can be applied in the real world to discover the pH's of various solutions. In the case that one has a solution of unknown concentration of acid/base substances, the analyte, this lab proved that with the respective acid/base opposition, the titrant, it is possible to find your unknown variable.

Citations

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